# Thermal analysis and structural upgrading of BEPCII R340Q04 transition section vacuum chamber

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**Abstract:** It is necessary to consider synchrotron radiation power in the vacuum chamber design and well operation，which is caused by the electron beams pass through the bending magnets. In this paper, synchrotron radiation power of collision mode in BEPCII R340Q04 transition section vacuum chamber is calculated; makes thermal analysis using ANSYS codes and compares the results with actual data in operating conditions. Finally the vacuum chamber upgrading structure design is completed according to above simulation and analysis. And thermal analysis results of new structure are given too.
**Key words:** Synchrotron radiation power Thermal analysis Structural upgrading

**1-Introduction**

BEPCII is a two-ring $e^+e^-$ collider running in the tau-charm energy region (Ecm = 2.0-4.2 GeV), which, with a design luminosity of $1 \times 10^{33}$ $cm^{-2}s^{-1}$ at the beam energy of 1.89 GeV, is an improvement of a factor of 100 over its successful predecessor, BEPC. The upgrade will use the existing tunnel, some major infrastructure items, and some of the old magnets [1]. R340Q04 transition section vacuum chamber is one section of the BEPCII storage ring. This vacuum has a higher power due to the synchrotron radiation light irradiation of the two upstream bending magnets. Therefore we need to calculate the temperature rise and place temperature probes for temperature monitoring. In this paper, synchrotron radiation power of irradiation on the vacuum is analyzed and calculated; and ANSYS thermal analysis results and actual testing data are compared. The structure of the new scheme' space is very limited, and not be able to complete to meet the cooling water channel space. In order to reduce the difficulty of manufacturing, increase the thermal effect, oxygen-free copper brazed structure is used to instead of stainless steel welding structure. Thermal analysis for the new structure was made finally.

**2- Synchrotron radiation power calculation**

R340Q04 transition section vacuum chamber is in third quadrants of BEPCII storage ring. In upstream area, there are bending magnets R3OMB01 and R3OWB.Part of the synchrotron radiation light from the two bending magnets shines on the inner wall of the chamber, except most parts absorbed by the photon absorbers. The schematics of synchrotron radiation light path shows in Fig.1.

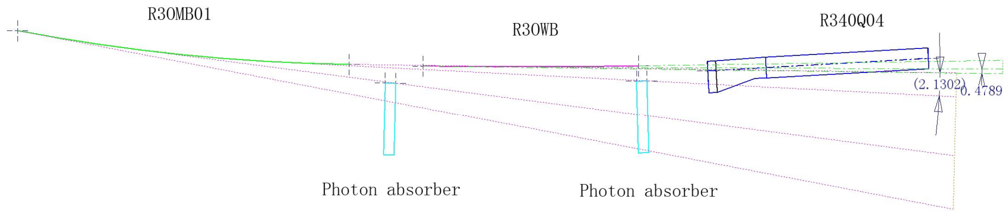



Fig.1 The schematics of synchrotron radiation light path

According to the theory, in collision mode of BEPCII, $E$=1.89GeV, $I$=0.7A, $\rho_{MB}$=9.15m, $\rho_{WB}$=36.59m, and the total synchronous optical radiation power can be expressed as [2]:

$$P_{SR\_MB} = \frac{88.5E^4 I}{\rho_{MB}} = 86.3908\text{KW} \tag{1}$$

$$P_{SR\_WB} = \frac{88.5E^4 I}{\rho_{WB}} = 21.6036\text{KW} \tag{2}$$

From fig. 1, the angle of the synchronous optical radiation received from R3OMB01 is 2.1302°and R3OWB 0.4789°.So the total power is:
$P=P_{MB}+P_{WB}=511.19+28.74=539.93$W

### 3- The old structure of R340Q04 transition section vacuum chamber

The material of the old structure is stainless steel. Cooling water channel is placed on the outside of the vacuum chamber where is around the synchrotron radiation area. It connects with the upstream and downstream vacuum chamber by knife-edge flanges. The model is shown in fig.2.

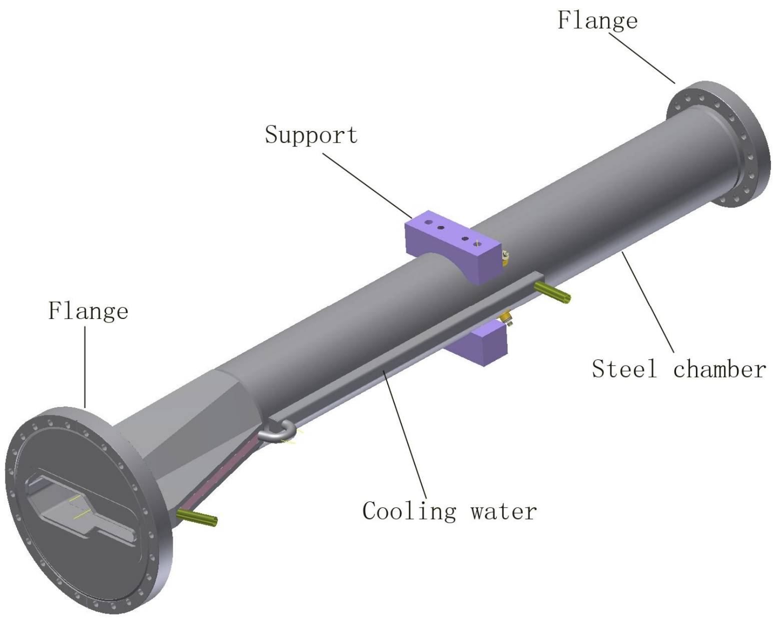
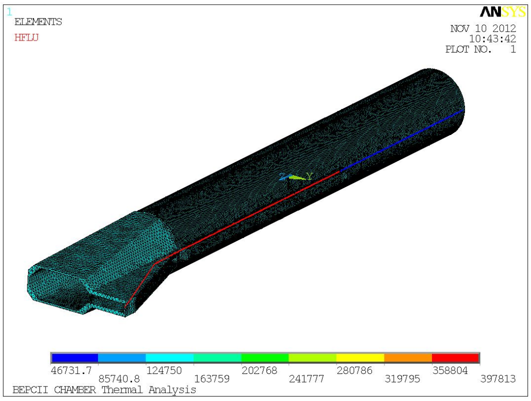



Fig.2 Schematic drawing of the old structure

### 4- Steady-state thermal analysis of the old structure [3]

### 4.1- FEM model and boundary conditions

To simplify the model, removing some unimportant structures, fig. 3 shows the FEM mesh with synchrotron radiation power load. Forced water cooling condition has been considered. Convective heat transfer boundary condition is used, which is shown in fig.4.



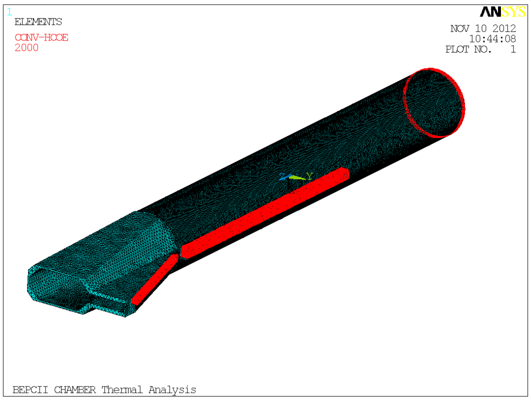




Fig.3 FEM mesh with synchrotron radiation power    Fig.4 FEM mesh with water cooling condition

### 4.2- Steady-state thermal analysis

According to the characteristic of the energy deposition, steady-state heat transfer analysis is performed to determine the temperature distribution. The maximum temperature is about 159.9℃ which is located on the regions not covered cooling waters. The temperature distribution of the old vacuum chamber is shown in Fig.5.

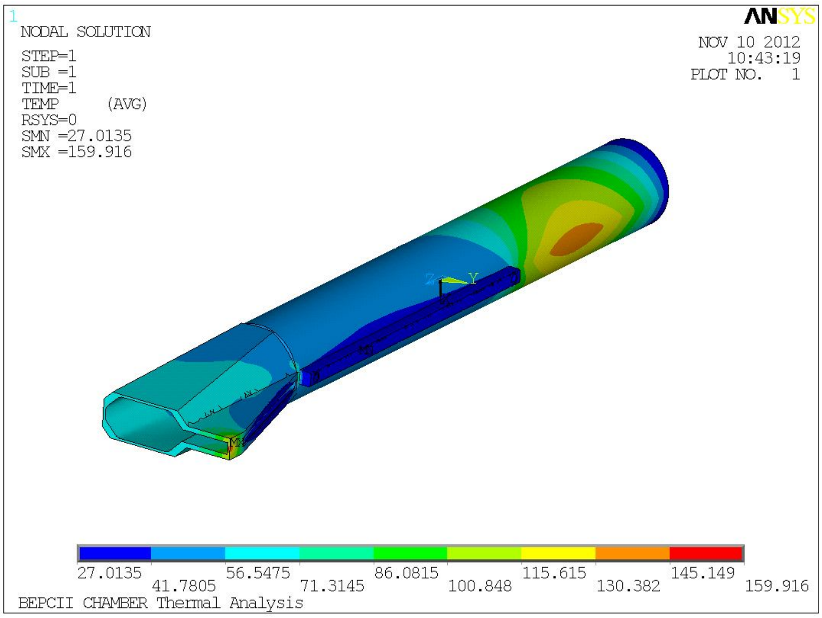



Fig .5 The temperature distributions of the old vacuum chamber

### 5-Transient thermal analysis and comparison with monitoring data

### 5-1 monitoring data of beam current intensity and temperature

Beam current intensity and temperature data can be got from BEPCII Database by software. Fig.6 shows the curves of the beam current intensity and temperature data at time from 0:00 to 8:00 am in January 11, 2011. Green and purple line represents the current intensity curve, corresponding to the left inner longitudinal coordinate units:

mA. Blue and red line represents the current intensity curve, corresponding to the left outer longitudinal coordinate units: ℃. Abscissa indicates the time and the unit is h.

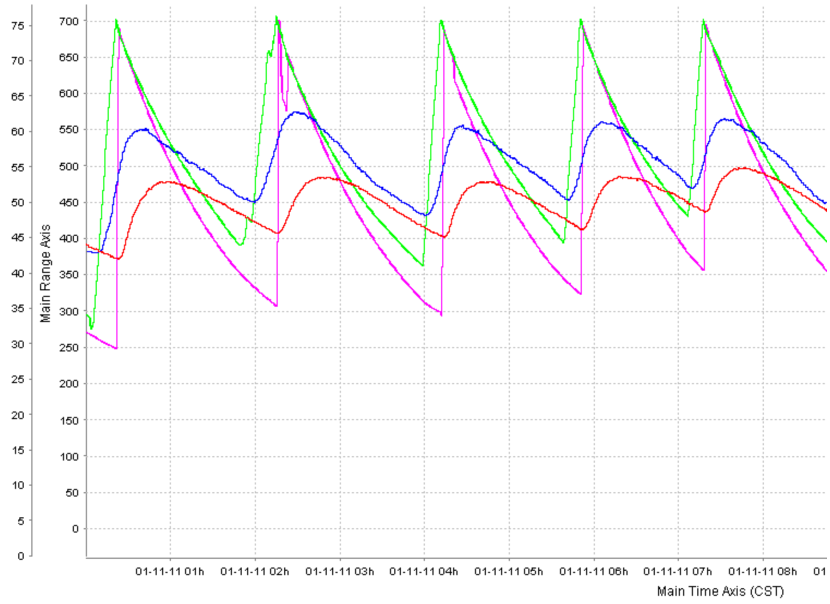



Fig .6 The curves of beam current intensity and temperature data

**5-1 Transient thermal analysis**

Synchrotron radiation intensity is proportional to beam current intensity. So transient thermal analysis is made by using polyline to approximate the actual beam current intensity. Fig.7 shows the transient thermal analysis results. From the beginning of the second cycle, the temperature tends to a steady state, which is very close to the temperature changes and monitoring results. Because of that it is not very sure the precise location of the temperature probes and a simplified calculation, there are some minor differences, but they are in acceptable range.

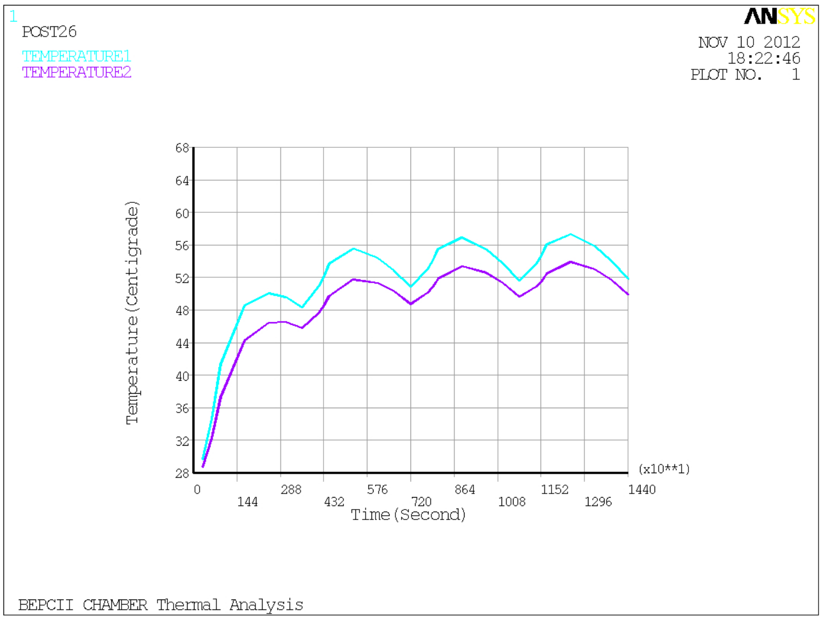



Fig .7 The curves of the temperature of transient thermal analysis

**6- The new structure of R340Q04 transition section vacuum chamber**

There are no fully space to set enough cooling water channels in the upgrading scheme. In order to reduce the difficulty of manufacturing, increase the thermal effect, oxygen-free copper brazed structure is used to instead of stainless steel welding structure. Fig.8 shows the model of the new structure. The stainless steel part is made of upper and lower half piece welded, then brazes with oxygen-free copper tube totally.

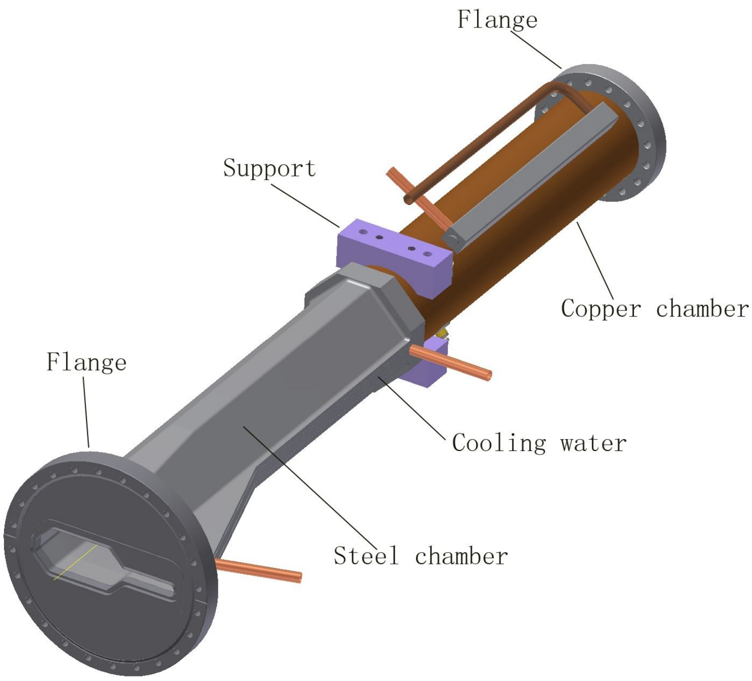
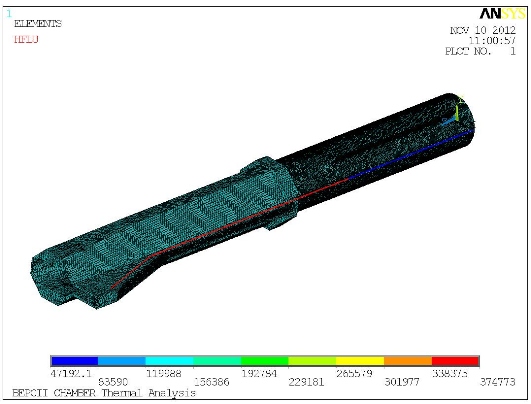



Fig.8 Schematic drawing of the new structure

## 7- Steady-state thermal analysis of the new structure

### 7.1- FEM model and boundary conditions

To simplify the model, removing some unimportant structures, fig. 9 shows the FEM mesh with synchrotron radiation power load. Forced water cooling condition has been considered. Convective heat transfer boundary condition is used, which is shown in fig.10.



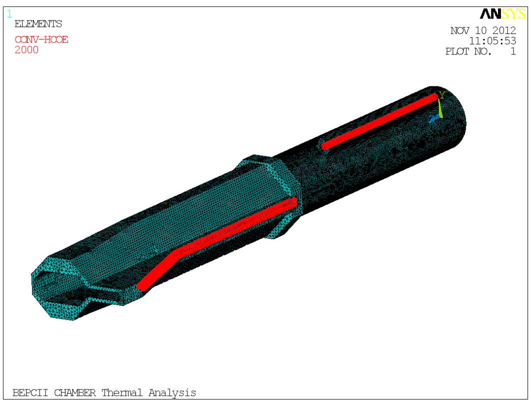




Fig.9 FEM mesh with synchrotron radiation power    Fig.10 FEM mesh with water cooling condition

### 7.2- Steady-state thermal analysis

According to the characteristic of the energy deposition, steady-state heat transfer analysis is performed to determine the temperature distribution. The maximum temperature is about 434.7℃ which is located on the regions not covered cooling waters. The temperature distribution of the new vacuum chamber is shown in Fig.11. Due to space limitations, the temperature around the synchrotron radiation power area without cooling water pipes is higher than old structure. The vacuum chamber can still work normally. These should be carefully designed and taken seriously into consideration in the process of operating.

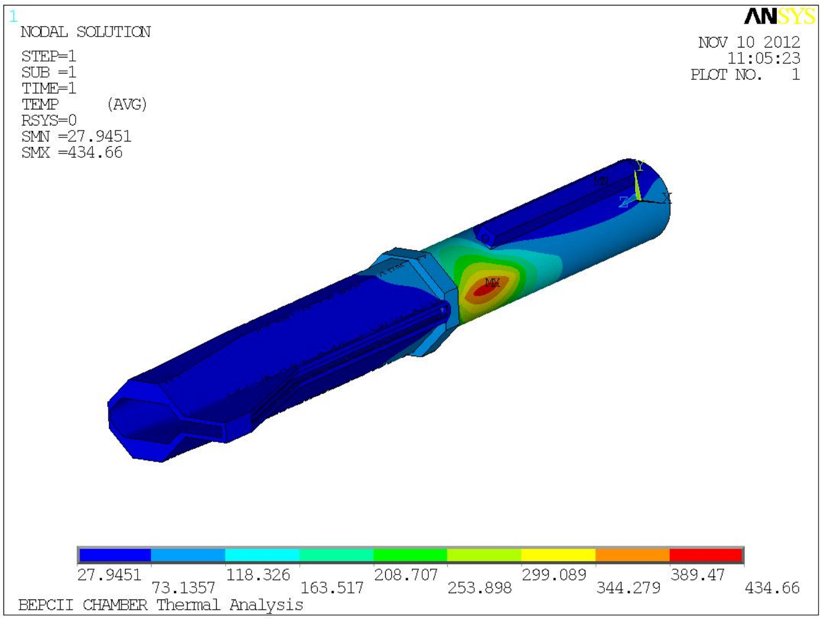



Fig .11 The temperature distributions of the new vacuum chamber

## 7- Conclusions

The structures of BEPCII R340Q04 section vacuum chamber before and after upgrading are described. Steady state and transient thermal analysis are performed to determine the temperature distributions by using ANSYS codes. The simulation results are compared with actual data in operating conditions. The temperature in some parts of the new vacuum chamber structure is higher for the reason that there is not enough space to set enough cooling water channels. But it still can work well.

## References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